GPS guided auto sensing system for motor vehicles

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Abstract

Driver errors are the most common cause of traffic accidents. Mobile phones, in-car entertainment systems, traffic volume increases, road systems becoming complicated contribute towards such driver errors. This paper introduces developing a GPS guided auto pilot system for vehicles. This system will be a driverless vehicle system. The user has to give the location of the destination to the system and then the system will automatically navigate to the given destination. These systems are currently used in aircraft, submarines and ships but not used in ground vehicles. Use of such systems in the open street is more complex than use of such systems in air or marine systems. The possible route to the destination must be selected by the vehicle after the destination coordinates are given by the user. Then the vehicle navigates through the open streets without colliding with other moving or non-moving objects. GPS sensor takes real time coordinates of the vehicle and decide the direction to be moved with respect to the given destination coordinates and pass control signals to the motor controller. While navigating, the vehicle keeps appropriate safe distance and speed with the vehicles in front of it. If the lane is not clear, the vehicle applies breaks to avoid collisions. Sonar sensors are used to detect the object in the road as they are more convenient in the outdoor applications. With further developments, this system will be able to assist drivers who drive long trips and play a vital role in minimizing road accidents.

Keywords: *Global Positioning System, auto pilot system, vehicle navigation*

1. Introduction

1.1. Background

An autonomous robot is a self-piloted vehicle that does not require an operator to navigate and accomplish its tasks. There are two categories in autonomous navigating named as indoor navigating and outdoor navigating. Indoor navigation can be seen as line follower robots, RFID based navigation, Wireless network-based navigation etc. Outdoor navigation is widely based on GPS. In the outdoor navigation category, auto-piloted vehicles are a recently developed subset of robotics and can come in three general forms; air, ground and submarine. Auto-pilot technology is widely used in both air and submarine forms except in ground form because in ground form there are more parameters that have to be considered when auto-piloting rather than the other forms. The term "Auto-pilot" is not a term widely used when referring to ground vehicles. Implementing of auto-pilot system for ground vehicles is more complex, since roads have more traffic density than the air and the marine systems. But introduction of these systems will be helpful for many motorists such as older people who are not fit enough to drive long distances or have some physical handicap. These systems take decisions after obtaining information from the environment, and do not take unjustified risks. Therefore, number of potential accidents will be lowered when such systems are used.

Global Positioning System is a widely-used tool in navigation, cartography and land surveying. United States Department of Defense initially developed the GPS technology for their military activities. But they had applied a selective error in those systems to avoid having more precise data for the hostile forces. In May 01, 2000, US president Bill Clinton ordered the US defense to stop jamming signals and to turn off selective error function that prevented other users to have pinpoint accuracy [1]. There are twenty-four satellites placed in the orbit to transmit data for the GPS receivers [2].

To calculate the location of a receiver it must receive signals from at least three satellites for a 2D fix and at least four satellites for a 3D fix [3].

There are several advanced studies that have been done in this field in both laboratory and commercial scale. Most of the leading automakers such as Mercedes, Audi, and BMW invest on this field. Among them Tesla introduced an auto-pilot system called advanced driver assistance system for their vehicles in October 2015 [4].

Yamaha Motors developed a robotic chauffeur named Motobot which is able to ride a motor bike without any aid from the human being. Apart from developing an auto-pilot system, they have created a robot who can ride the bicycle on the race track with the performance similar to a professional racer. That robot also can detect objects, detect curves and curbs and navigate to the given destination [5]. Department of the Transactions of the Chinese Society of Agricultural Engineering has developed an autonomous navigating system for linear move sprinkler machine based on GPS. That rover was also capable of navigating to the given GPS location in a linear way, autonomously. It was equipped with a microcontroller, navigation controller, speed steering controller, GPS sensor and a digital compass sensor [6].

1.2. Objectives

The purpose of this study was to develop an algorithm to identifying the location given by the user and to analyze the behavior of the moving and non-moving objects on its way for steering the vehicle through the streets. The vehicle must be able to identify the angle which it is heading according to the destination. The rover should be able to go forward if its' lane is clear. Otherwise it must stop or maintain appropriate speed and distance with the front vehicle. It should not be collide with the any of the objects on its track.

2. Problem statement

Developing an auto-pilot system for ground vehicles will address several problems in the open streets. Number of road accidents occur because of the risky decisions taken by the drivers. Sometimes they cannot take correct actions or reactions within a limited time period. Lack of vision, slow reaction speed are main causes for those accidents. The proposed system acts as an assistant to make those decisions. The system takes decisions based on the sensors mounted to the vehicle and the given algorithm. So, this system helps to take more precise and timely decisions.

There are several factors affecting the precision and accuracy of GPS data. They are,

a) Number of visible satellites
b) Satellite geometry
c) Satellite clock errors
d) Receiver errors

Because of these errors, it cannot be solely dependent on GPS data to navigate a vehicle. Therefore, some other sensors must be added to evaluate the surrounding of the vehicle. Sonar sensor is the best match to "know" the surrounding. Then with the aid of sonar sensors vehicle can navigate to the given destination without any collisions. That means sonar sensors aid the main objective, which is self-navigating to the destination.

3. System modeling

3.1. Overview

This study consists of several parts as listed below,

a) Designing and fabricating the rover's chassis.
b) Selecting the appropriate components.
c) Building the Collision avoiding algorithm.
d) Building the GPS navigating algorithm.
e) Programming the rover

3.2. Methods and techniques

3.2.1. Designing and fabricating the rover's chassis

To demonstrate the developed algorithm, the rover must act similar to an actual vehicle. Most of the RC cars in the open market fulfill that requirement. It has single motor to power the rear wheels with a differential system. Steering is done using another motor. It consists front and rear spring suspension system which assist smooth mobility on the streets. The study used the RC car and disassembled to fix sensors and controllers.

The motors must be operated according to the signals given by the microcontroller. Microcontroller unit analyses the data from the GPS sensors and the sonar sensors according to the developed algorithm and gives command to the motors.

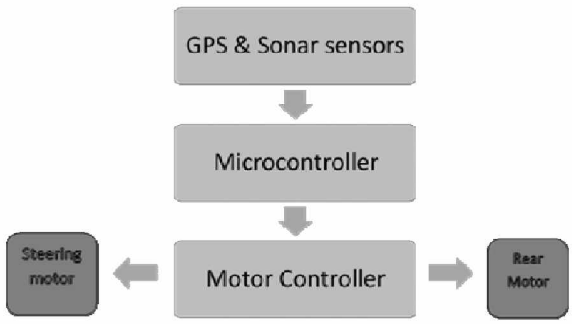

Figure 1. Block diagram of the rover.

3.2.2. Selecting the appropriate components.

In this rover, several electronic components have been used.

a) Arduino Mega Microcontroller
b) L239D Motor controller
c) GPS sensors
d) Sonar sensors
e) HMC 5883L Compass Sensor

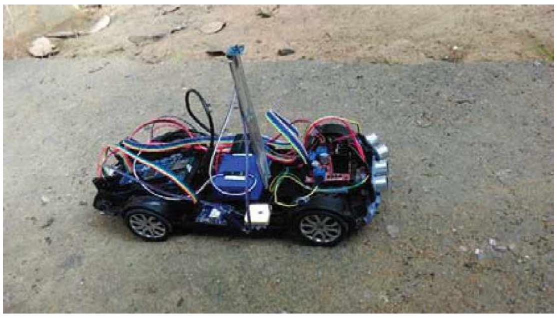

Figure 1. Assembled Rover.

a) Arduino Mega Microcontroller

Arduino Mega 2560 is used as the microcontroller in this system. It gets input signals from the GPS sensor and the Sonar sensors. Then it processes the signal according to the given algorithm and supply output signals to the motor controller to drive the motors. Microcontroller is programed using Arduino IDE.

b) L293D Motor controller

L293D is a typical Motor driver or Motor Driver IC which allows DC motor to drive on either direction. L293D is a 16-pin IC which can control a set of two DC motors simultaneously in any direction [7].

c) GPS sensor

Technical data sheet describing the cost effective, high-performance u-blox 6 based NEO-6 series of GPS modules that brings the high performance of the u-blox 6 positioning engine to the miniature NEO form factor. These receivers combine a high level of integration capability with flexible connectivity options in a small package. This makes them perfectly suited for mass-market end products with strict size and cost requirement.

d) Sonar sensors

The HC-SR04 ultrasonic sensor uses sonar to determine distance to an object like bats or dolphins do. It offers excellent non-contact range detection with high accuracy and stable readings in an easy-to-use package. From 2cm to 400 cm or 1" to 13 feet. Its' operation is not affected by sunlight or black material like Sharp rangefinders are (although acoustically soft materials like cloth can be difficult to detect). It comes complete with ultrasonic transmitter and receiver module [8].

e) Digital compass

The HMC5883L sensor is a 3-axis digital magnetometer IC designed for low-field magnetic sensing. Communication with the HMC5883L is simple and all done through an I2C interface. Need to connect power, ground and only two cables to Arduino board (SDA, SCL).

The HMC5883L board can be powered up by 5V or 3.3V pins of Arduino board.

3.2.3. Building the collision avoidance algorithm

This algorithm depends on data received by the sonar sensors. There are three sonar sensors mounted in the rover. One on the front and another two on the left and the right hand sides.

Depending on the data being received by the sonar sensors, algorithm divides into two parts.

a) Braking
b) Keeping the appropriate distance with the front vehicle

a) Braking

Braking of the vehicle is done when the vehicle has not enough space to move in front. For an example, vehicle in the front is stopped and the next lane is not clear to overtake, then vehicle should have to brake and stop itself. For applying the brakes, vehicle should determine its braking distance with respect to the current velocity. In this demonstration system, braking is done by cutting out the current supply to the motors by PWM signals.

b) Keeping the appropriate distance from the front vehicle

If there is another car is moving in front of the rover, it should maintain its distance with respect to the front car. A constant value is given to the rover which is known as the safe distance. If the distance between two cars is equal to that value, rover decelerate to a safe speed in order to maintain the distance.

3.2.4. Building the GPS navigating algorithm

a) Autonomous GPS navigation is done in several parts.
b) Identifying the current location
c) Identifying the destination
d) Selecting the possible route
e) Identifying the current headed direction with respect to the destination direction.
f) Steering the rover

The rover can identify its current location using the satellite data from the GPS sensor. It takes its latitude and longitude to determine the location. When the user enters the destination, it takes the latitude and longitude values of the destination. The rover determines the direction which it should move and emit control signals to the motor controller. While navigating, the rover obeys the algorithm for collision avoidance.

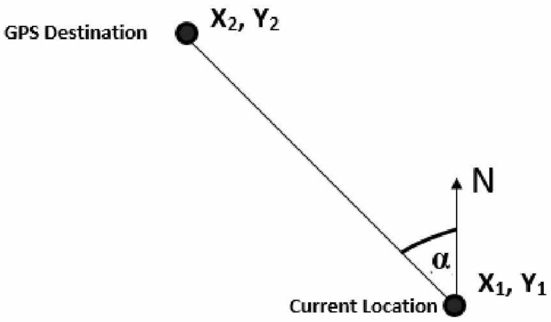

Figure 2. Turn angle between the destination and the north direction.

$$\tan \alpha = \frac{(Y1-Y2)}{(X1-X2)}$$

$$\alpha = \tan^{-1} \frac{(Y1-Y2)}{(X1-X2)}$$

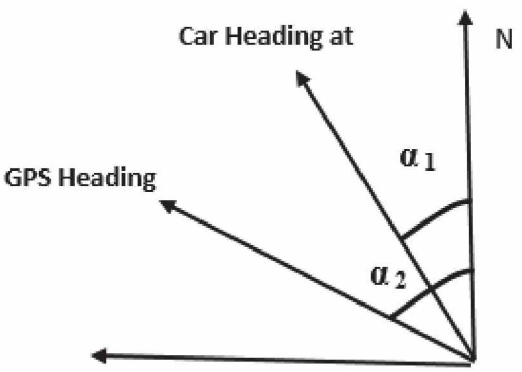

Figure 3. Angle difference between the destination and the rover direction with reference to the north direction.

If $\alpha_1 > \alpha_2$ Vehicle turns right

If $\alpha_1 < \alpha_2$ Vehicle turns left

The north of planet and magnetic north is not the same point. Magnetic north is some distances off the North Pole. Therefore, some value called "declination angle" must be added to get actual north when we use compass. While testing, the rover declination angle was calculated using the data from an online reference map.

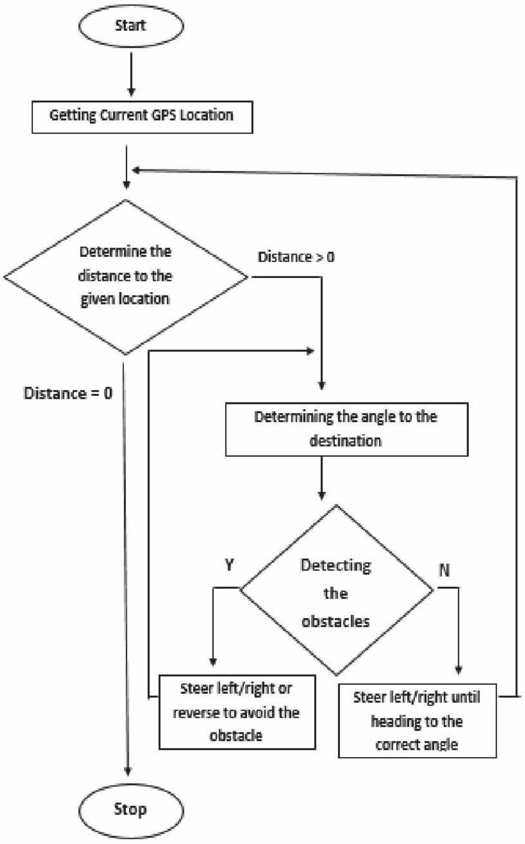

Figure 5. Flow chart of the algorithm.

4. Speed analysis of the developed system

Table 1. Test data.

Action	Distance of the Path (m)	Percentage of Successes trials at $0.5ms^{-1}$ Speed (%)	Percentage of Successes trials at $0.25ms^{-1}$ Speed (%)
1	50	55	70
2	50	70	80
3	50	60	70
4	50	60	70
5	50	65	75
6	50	70	80

Action Description

1 - Autonomous GPS navigation done in several parts
2 - Identifying the current location
3 - Identifying the destination
4 - Selecting the possible route
5 - Identifying the current headed direction with respect to the destination direction
6 - Steering the rover

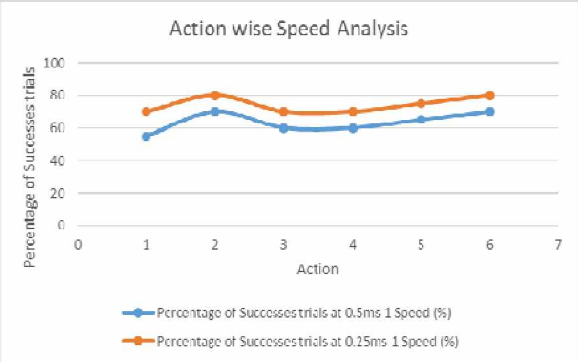

Figure 4. Action wise speed analysis.

Following hypothesises are considered to check the significance of different actions

Hypothesis
H_0 – There is no significant difference in the speed at $0.5ms^{-1}$ and developed system based on action.
H_1 – There is a significant difference in the speed at $0.5ms^{-1}$ and developed system based on action.

Chi-squared test was applied to check the above test hypothesis and results are shown in Table 2.

Table 2. Chi-Square Goodness-of-Fit Test for Observed Counts in Variable: Success of trials at 0.5ms-1

Action	Observed	Test Proportion	Expected	Contribution to Chi-Square
1	56	0.166667	64	1
2	72	0.166667	64	1
3	63	0.166667	64	0.01563
4	60	0.166667	64	0.25
5	65	0.166667	64	0.01563
6	68	0.166667	64	0.25

Results of chi-squared test indicate that there is no significant difference in success of trial according to the given 6 actions at 0.05 significant level (P-value = 0.772)

Hypothesis
H0 – There is no significant difference in the speed at 0.5ms-1 and developed system based on action.
H1 – There is a significant difference in the speed at $0.25ms^{-1}$ and developed system based on action.

Chi-squared test was applied to check the above test hypothesis and results are shown in Table 3.

Table 3. Chi-Square Goodness-of-Fit Test for observed counts in variable: Success of trials at 0.25ms-1.

Action	Observed	Test Proportion	Expected	Contribution to Chi-Square
1	70	0.166667	74.1667	0.234082
2	80	0.166667	74.1667	0.458801
3	70	0.166667	74.1667	0.234082
4	70	0.166667	74.1667	0.234082
5	75	0.166667	74.1667	0.009363

Results of chi-squared test indicate that there is no significant difference in success of trial according to the given 6 actions at 5% significance level (p-value = 0.898)

4.1. Collision analysis

Active collision avoidance system is tested against both moving and non-moving objects. For non-moving objects, the number of collisions, when the rover moves at 0.5 ms^{-1} is 10%, and for moving objects, the number of collisions when the rover moves at 0.5 ms^{-1} is recorded as 40%. Even if the rover moves at 1 ms^{-1}, the proportion of non-moving objects remains the same, but in the case of moving objects, the collision ratio increases up to 60%.

5. Result and discussion

In general, the rover could move through a given path without collisions with the objects in its path. It could stop when the lane is not clear and could maintain safe distance with the vehicle in front of it. Steering was done smoothly.

When considering the GPS navigation, it was not a success due to various reasons. The current location of the rover was not precisely accurate and had an error of about 25m air distance. For that level of inaccuracy of the data as mentioned in the problem statement, there could be several reasons this might affect the results. Another major error occurs when the on-board CMOS battery drains. The battery is there for retaining data and nonvolatile storage for configuration. Normally the battery is a rechargeable one. It takes more than two hours to recharge at the initial starting point. The battery status affects also the data accuracy. To have a better accuracy, the battery must be at 5v.

For obstacle avoidance and collision avoidance, sonar sensors are the best match rather than IR sensors, Sharp IR sensors or Laser range finders. As this system is for the outdoor applications, IR based sensors are not suitable because it has considerable amount of noise occurrence with sunlight. Laser range finders are accurate, but cannot be used to detect objects with a small width such as poles. But the sonar sensors have no interaction or noise generation due to sunlight, colour of the material or the width of the object. It has little amount of noise effect due to the echo signals from the other sound generating object. But relatively to the other sensors the error due to noise is negligible.

The compass module was initially mounted on the rover chassis. But when the rover is moving, magnetic field which was generated from the motors affected the accuracy of the compass. Therefore, the compass was mounted high from the motors, to reduce the magnetic field effect.

6. Conclusion and future work

Driverless vehicle is a task which almost all the vehicle manufacturing companies are trying to develop. They use most advanced technologies in there research studies. Most important in this kind of system is the accuracy as the system directly deals with human lives. So, when the accuracy is higher, the probability to make accidents become minimal. That's why the pinpoint accuracy of data is needed in such a system.

This system can be applied to the motor vehicle as an auto piloting system such as in aircraft. One problem the drivers face most of the time is getting bored while driving for long distances such as in highways. By implementing this system to the vehicles, drivers can take a rest whenever they want without stopping the vehicle. Handicapped people also can easily travel wherever they want because this system assists the driver while driving. As speed controlling, braking is done automatically after analyzing the surrounding, chances for accidents t occur will be decreased.

In the proposed system, collision avoidance algorithm is solely relying on the sonar sensors. But accuracy of collision avoidance can be increased by combining the vision-based sensor, such as real time image processing techniques with the sonar sensors. Then the vehicle will receive better understanding about the surrounding.

In this study, destination which the user needs to go is given by the latitude and the longitude values. This is not user-friendly. Hence, this research can be extended to input the destination directly by name of the place or selecting the destination in a map.

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